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FOSS FDM Electrooptical Tow Cable Termination

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(UFOCS) Workshop, Johns Hopkins
University, Laurel, Maryland, 16 May 1983

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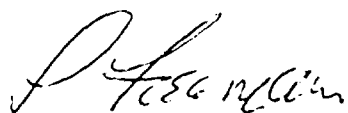
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Preface

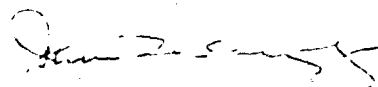
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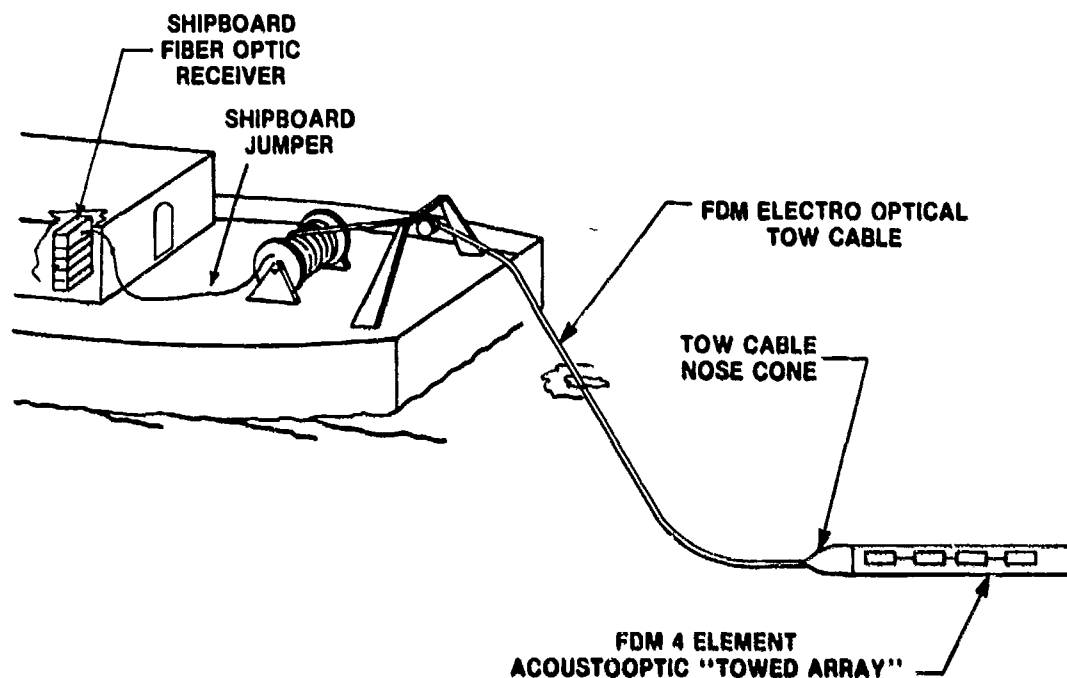
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20. Continued:

contains three wires and three multimode optical fibers, was mechanically, electrically, and optically terminated within a pressure-proof nose cone. Optical throughput losses of less than 2.0 dB per connection have been achieved using Hughes optical contacts. Tensile and pressure testing has verified the termination's performance.

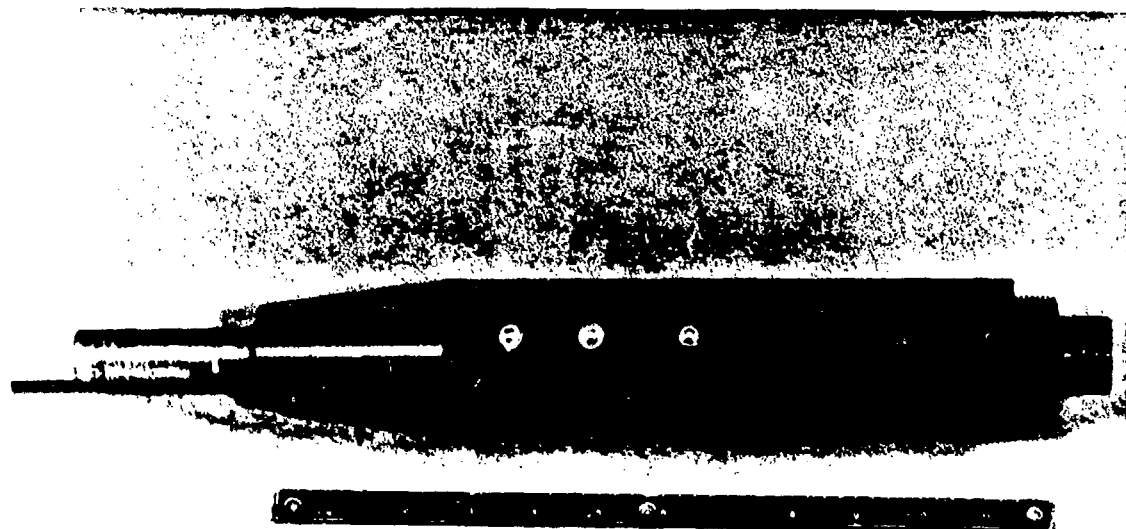
FOSS FDM Electrooptical Tow Cable Termination



Slide 1

The Feasibility Demonstration Model (FDM) Project is that portion of the Fiber Optic Sensor System Program (FOSS) that uses an optical sensor and demonstrates its feasibility in a Navy System. The sensor being used is the interferometric fiber optic hydrophone. It will be utilized as the acoustic element in a "typical" towed array system. This system includes the towed array, a digital optical data transmission system, an electrooptic armored tow cable, and a shipboard fiber optic receiver.

A

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Today, I will address the interface between the ocean end of the quadruple armored tow cable and the leading edge of the towed array. Shown here is the vehicle used to effect this junction — the tow cable termination nose cone. This termination is the means for transitioning the cable's strength to the towed array as well as connecting the three multimode optical fibers and three electrical wires. This connection uses redundant sealing throughout, and can withstand hydrostatic pressures to 3000 psi. The cable's strength is transitioned with a poured epoxy socket type of termination. Optical connection throughput losses of less than 2.0 dB have been accomplished using optical contacts supplied by Hughes Aircraft Company's Connecting Devices Division. These, along with three electrical contacts, are housed in an 11/16-inch (diameter) six-pin electrooptical connector.

NOSE CONE DISCUSSION

- **CONNECTOR - USE HUGHES CONTACTS**
- **CABLE PREPARATION**
 - **MONEL SERVING FOR STRAIN RELIEF**
 - **REMOVE 4 ARMOR LAYERS IN STAGGERED FASHION**
 - **INSTALL DAM AND CORE SEALS**
 - **REMOVE POLYETHYLENE SHEATH; EXPOSING FIBERS AND WIRES**
- **CONNECTOR ASSEMBLY**
 - **INSTALL CONTACTS**
 - **LINKED TO DAM WITH CLAMSHELL AND SPLIT SPACER**
- **TERMINATION'S STRENGTH**
- **SPECIAL SEALING TECHNIQUES**
- **PROTOTYPE TESTING**

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My discussion of the FDM tow cable nose cone termination will include the electrooptical connector with its low loss Hughes optical contacts; the cable preparation necessary to accept this termination; the special dam and core seals used on the cable core; the termination's method of transitioning the cable's strength; and our prototype testing.

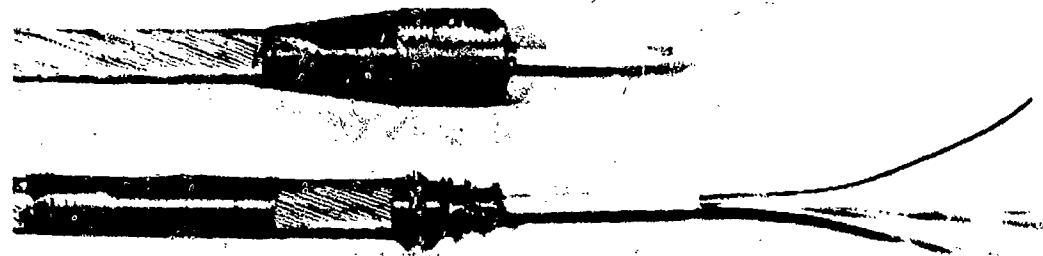


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The electrooptic connector was jointly designed with Hughes Connecting Devices Division. The connector uses the Hughes single pin contact seen here as its basic building block. This contact is assembled by inserting cleaned fiber into the center, epoxying it in place, and then polishing the optical surface. One of the individual contacts is equipped with Belleville washers which provide a positive pressure when mated.

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We see here three single contacts along with three electrical pins installed into an aluminum connector body. The body is designed to accept the contacts yet still allows them to float, guaranteeing proper mated alignment. The back side of the connector body is grooved to accept the clamshell assembly, which protects the slack bare fibers and wires necessary for pin alignment. Optical connection throughput loss was specified to be less than 2.0 dB. Acceptance testing showed an average loss of approximately 1.6 dB.



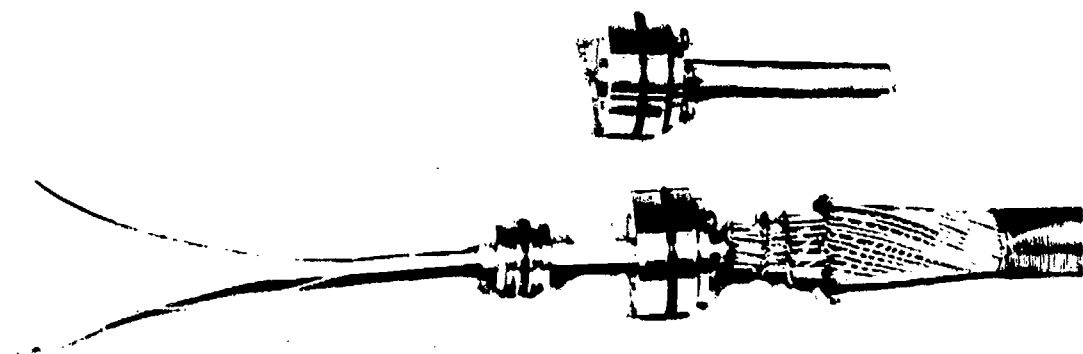
Slide 6

The FOSS FDM tow cable is comprised of an electrooptical core housing three multimode fibers and three wires. This core is sheathed in high density polyethylene and then covered with four layers of contra-helically wrapped galvanized extra improved plow steel.

The tow cable must be carefully prepared to accept the termination assembly. This is necessary for proper orientation within the housing — providing fiber slack for optimal optical performance and adequate strength member bonding surface area.

The first step after sliding the termination housing up the cable is to tightly apply a 4-inch permanent serving of monel wire. This serving is intended to reduce the bending fatigue of the cable armor as it exits from the tow point nose cone. This serving will be partially inside the nose cone during final assembly and that portion will become encapsulated by the epoxy potting material.

The second step of cable preparation is to remove all four layers of armor wire. A temporary serving of monel wire is installed on the outer armor layer. Each wire of this outer layer is unwound and bent back against this temporary serving until it forms a 90 degree bend from the cable center line. This bent wire is cut using a dremel tool equipped with an abrasive cutting disc, leaving approximately a 1/8-inch long hook. A second temporary serving is installed and the armor is unwound and cut in a similar fashion. A third and, finally a fourth temporary serving is installed and the last two armor layers are removed. The staggering of the armor wires in such a manner exposes more of the wire to the epoxy potting compound.



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The third step is to remove the four temporary servings and to prepare the core. A butyl nylon bedding jacket is removed from the exposed core, revealing the high density polyethylene sheath. The bitter end of the core is slightly tapered to facilitate installation of the redundant core seals.

The fourth step is to install the dam assembly onto the core. This includes the epoxy dam, the core support tube, and the 1/4-inch (inside diameter) O-ring assembly. The core support tube, which is attached to the dam, is used to keep epoxy from getting onto the core. This core support tube penetrates the area between the core and the bottom armor layer causing the layers of armor (once constrained by the temporary servings) to "birdcage," permitting penetration of the epoxy potting material. After the dam assembly is pushed into place under the armor, the O-ring assembly is squeezed down against the dam by evenly tightening the four number six screws. This process moves a boss in contact with the O-ring contained in the dam. In effect, the O-ring acts as a gland seal, creating pressure on the cable core. Thus, the first of two core seals is installed.

The fifth step is to install the second core seal. This redundant seal, housed within a seal block, is slid onto the cable core. It is notched on each side to accept the split spacer halves of the connector assembly, such that its final position will be determined during that assembly.

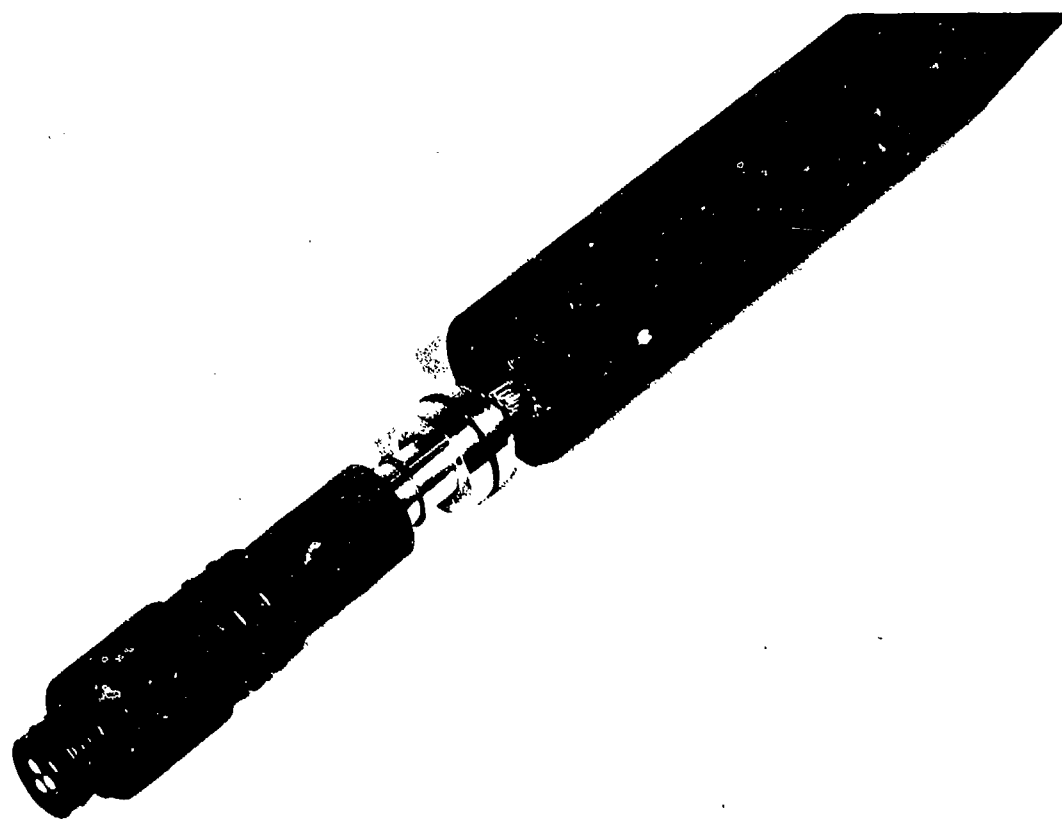
The last step prior to connector assembly is to remove the polyethylene core jacket, exposing the three multimode fibers and electrical wires. This jacketing is generally removed in approximately 2-inch long pieces, reducing the chances of fiber damage. At this stage the individual fibers and wires are cleaned, the optical and electrical contacts are installed, and these are inserted into the connector body. The optical contacts are throughput tested to ensure that they meet the 2.0 dB maximum loss per connection specification. The cable end is now ready for connector assembly.



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After optical specification verification has been completed, the split spacer is installed. This links the dam assembly and the seal block. Each half of the split spacer is slid over the core and fits into a recessed hole in the dam assembly, keeping the two halves together and centrally located. The other end of the split spacer is notched to accept the seal block.

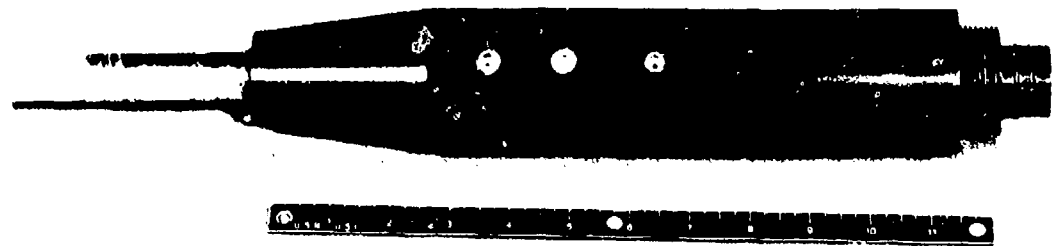
The next step is to install the clamshell that links the seal block to the connector receptacle. It is within this 4-inch long clamshell that 3/4 inch of fiber slack is accommodated. Care must be exercised to assure that this slack is well contained so that no damage occurs during subsequent handling. The connector is now directly linked with the dam assembly via the clamshell, the seal block, and the split spacer.

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The third step is to install the adapter over the entire connector assembly. The connector receptacle is equipped with a slot that must engage with the pin in the adapter, guaranteeing proper connector orientation.

The fourth step of the assembly takes the tow point nose cone, which had been slid up the cable, and threads it onto the adapter. The nose cone should be hand tightened in order to feel the assembled dam and connector components bottom out. At this point the assembly is complete and may be verified by applying finger pressure to the connector face, where there should be no movement. Upon completion of this check, the housing and adapter are locked together with the set screw provided, eliminating any relative motion between these two pieces.

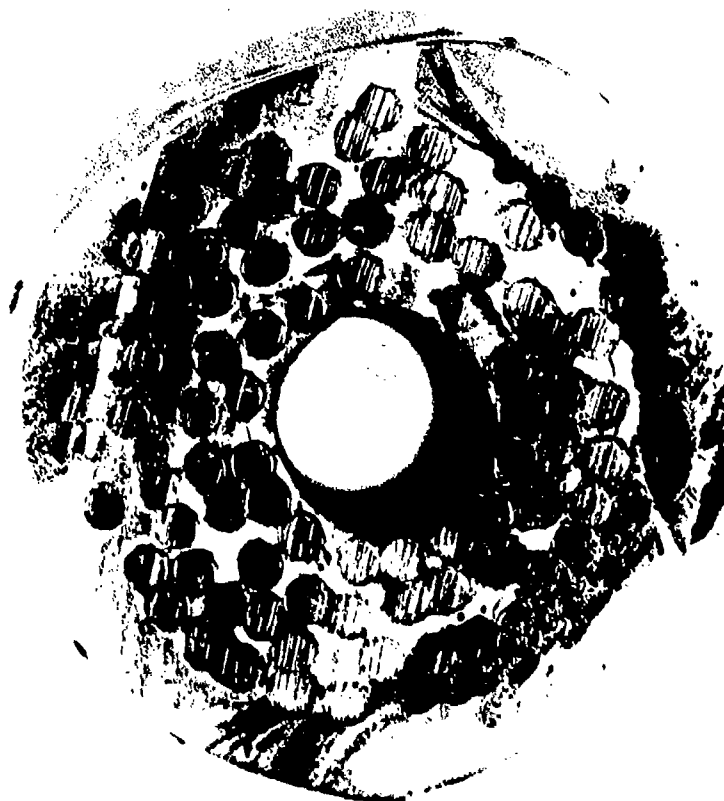
In the final step, the tow point nose cone is filled with epoxy and mineral oil using the three holes seen in the termination housing.

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The area where the cable enters the tow point housing is sealed with ductseal and secured with electrical tape. The tow point should be suspended vertically in preparation for epoxy pouring. The bottom two pipe threaded holes are used to fill the portion behind the dam with high bond strength epoxy. Pipe plugs wrapped in Teflon tape are used to seal these two holes after filling. Epoxy cure time is four hours, after which the tow point can be positioned horizontally in preparation for oil filling. The cavity forward of the dam is secured by the remaining pipe threaded hole. Mineral oil is used in this cavity as an additional safety feature.

On any permanent nose cone installation a length of cable and a portion of the tow point housing will be overmolded with a tapered cone of flexible urethane. This strain relief ensures less bending and vibration fatigue of the cable at its entry point into the tow point housing.

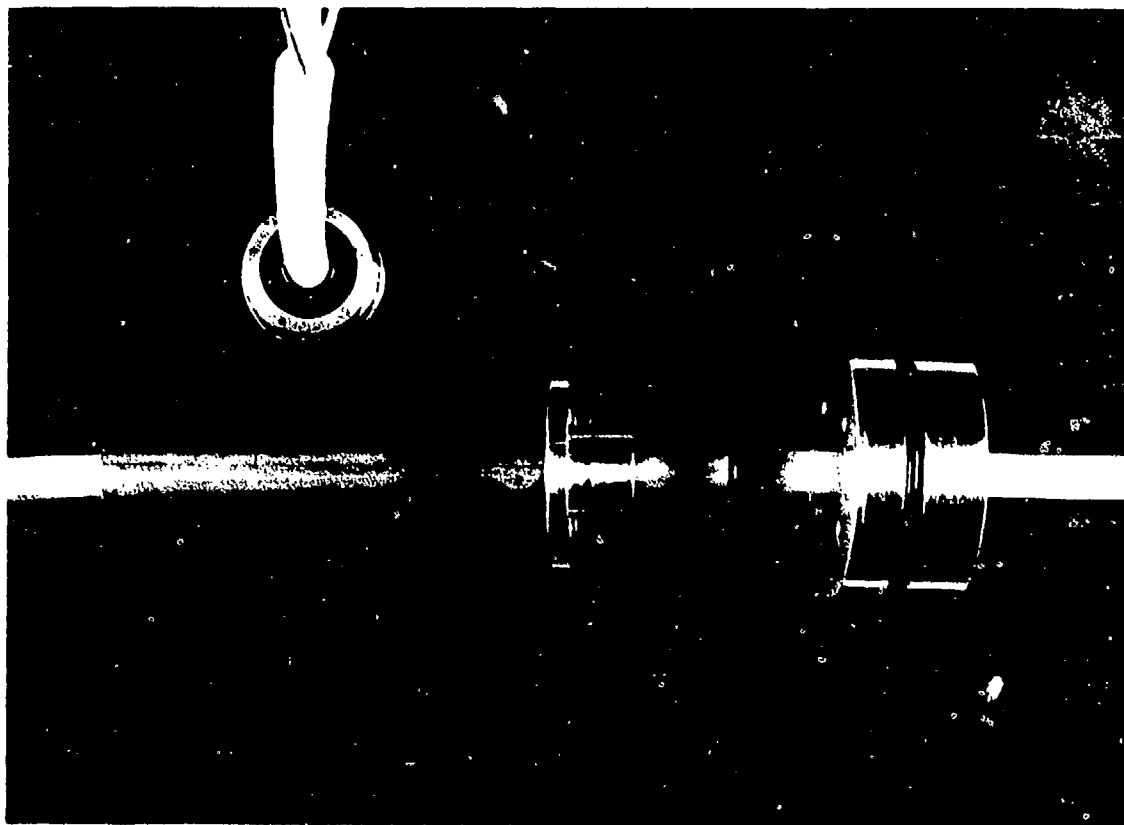
The FDM tow cable termination transitions the cable's strength with a poured socket type of termination. Care has been taken to pattern the tapered socket after standard industrial practice, where a 7.5 degree taper is used. This tapered socket, when housed inside a mating piece, will force compressional loading on the cable armor wires with any attempted motion of the socket. Theoretically, this means that the socket material need not even bond to the armor, but just have some frictional resistance. Our socket is poured around the "birdcaged" armor wires using a high bond strength epoxy. This two-part material has been specifically developed for excellent bond strength to the galvanized steel.



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Calculations, based on surface area of the cable's armor wires and the bond strength of the epoxy, show that this bonding alone will develop the cable's breaking strength. This assumes that there is good epoxy coverage within the interstices of the individual armor wires. This viewgraph shows a section of a test pour of the epoxy proving its excellent flow properties among the armor layers.

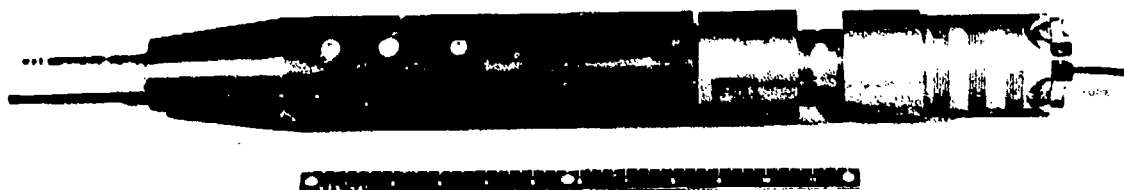
Prototype fabrication was made of 6061 T-6 aluminum for machining ease and light weight. Calculations show that a material change would be necessary for the termination to develop the full 60,000 pound breaking strength of the cable.



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The FDM tow cable nose cone termination has been designed to be mated pressure proof to 3000 psi. This has been accomplished by using double O-ring seals wherever possible in the design. This redundant sealing philosophy has been carried over to the area where conventional sealing techniques were not successful. This region is the required barriers on the high density polyethylene core. Sealing had to be accomplished in the dam area and redundantly in the seal block region. In the dam/core support tube assembly, a thick walled O-ring was used partially as an O-ring on the core and partially as a gland seal. Inside the seal block was housed a "Chevron" type seal made of fluorosilicone rubber. Each seal has been successfully pressure tested to 3000 psi; demonstrating our redundant sealing approach.

These unconventional seals were necessary because of the unreliability of conventional molding to the high density polyethylene. It should be noted that some companies have had recent success in urethane bonding after the polyethylene had been "plasma etched."



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Testing performed on the FDM tow cable nose cone termination was necessary to prove its mated pressure proof integrity as well as to characterize optical throughput as a function of pressure and tension.

We pressure tested a 25 foot piece of FDM tow cable (called the test tow cable). Each end was fully terminated with a nose cone termination. These terminations were each coupled to a mating assembly that housed electrooptic "jumpers" made of the high density polyethylene cable core. These jumpers each ran through a double gland seal in the pressure tank wall. This three piece assembly was optically monitored for throughput changes as a function of pressure and insulation resistance tested with a megohmmeter, checking for any water penetration.

Optical throughput changes of -0.1 to -0.2 dB were noted upon filling the tank, probably due to the cold tap water. Insulation resistance measurements greater than 10 gigaohms indicated all was well. The tank was pressurized to 2000 psi with only another -0.2 to -0.3 dB change in optical throughput. Insulation resistance measurements slightly increased. After four days, readings remained stable, demonstrating our pressure proof integrity.

Subsequent individual tests of the dam seal and the "Chevron" seals have showed them to be long term hydrostatic pressure proof to 3000 psi, giving confidence in our redundant sealing.

The FDM nose cone termination was also tension tested while being optically monitored for throughput changes. The test tow cable was used for this test as well. The cable was cycled to 5000 pounds tension with a maximum throughput loss of 0.52 dB. Earlier cable testing had shown this to be typical without connectors, demonstrating the success of our optical connection.

SUMMARY

- **PROTOTYPE ELECTROOPTICAL TOW CABLE NOSE CONE HAS BEEN FABRICATED**
- **STANDARD INDUSTRIAL FABRICATION TECHNIQUES**
- **"OFF THE SHELF" COMPONENTS**
- **PRESSURE AND TENSION TESTED**
- **OPTICAL THROUGHPUT CONNECTION LOSSES LESS THAN 2.0 dB**
- **FDM TESTING IN LATE 1983**

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In summary, a prototype electrooptical tow cable nose cone termination has been successfully developed using standard industrial practice and off-the-shelf material. Tension and pressure testing has demonstrated the prototype's operational capabilities while subjected to 3000 psi hydrostatic pressure and tensile loading to 5000 pounds. Optical throughput losses have been kept less than 2.0 dB using Hughes Aircraft Company's optical contacts. A prototype nose cone will be used to join the FOSS FDM tow cable to the FDM towed array in acoustic testing late in calendar year 1983. The technology developed for this nose cone termination easily lends itself to other underwater applications requiring high strength and pressure proof, low loss, optical connections.

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